Report as of FY2009 for 2009PA103B: "Developing Numeric Criteria to Guide Nutrient Controls for Streams in Pennsylvania"

Publications

- Articles in Refereed Scientific Journals:
  - Carrick, H.J. 2010. Benthic algae-nutrient relationships in Mid-Atlantic streams. Limnology and Oceanography In preparation.
- Conference Proceedings:
  -

Report Follows

FY09 PROJECT REPORT (FINAL REPORT)
Pennsylvania Water Resources Research Center

Developing Numeric Criteria to Guide Nutrient Controls for Streams in Pennsylvania

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PRINCIPAL FINDINGS AND SIGNIFICANCE

Problem Statement

The presence of polyphosphate-accumulating organisms (PAO) in stream biofilms appear to be a very significant sink for P in streams, and therefore can represent an previously unaccounted source of P that can be transported downstream during large flushing events (e.g., Chesapeake Bay). The current project will build further on this success by establishing numeric reduction criteria by developing rapid, economical assays to directly measure the degree of P saturation in streams ecosystems throughout Pennsylvania.

Objectives

Our objectives will be met by carrying out a series of experiments using natural biofilms collected from streams of varying nutrient content and relative productivity. Biofilms were sampled seasonally (winter, spring, summer, and fall) from streams already identified as having low, moderate, and high nutrient content within each of the two ecoregions (Appalachian Plateau and Piedmont) in the state's Water Quality Network (see Carrick et al. 2008).

1. Measure the uptake rate for inorganic and organic P among seasons and ecoregions to evaluate their relative correspondence.
2. Evaluate the phylogenic identity of phosphorus accumulating organisms.
3. Recommend P criteria for Pennsylvania streams (annual versus seasonal and state-wide versus ecoregion specific)

Review of Major Findings

Correspondence between APA and P uptake

Phylogenic Identity of P-storing Organisms

We investigated whether this biological transformation among phylogenic groups should be included in stream P models. To date, the answer appears to be yes. Both prokaryote and eukaryotes are responsible for P-storage within the biofilms retrieved from these streams. We obtained positive hits for the presence of poly-phosphorus storage for both taxonomic groups using DAPI (4',6-diamidino-2-phenylindole, DAPI) staining. Moreover, the presence of poly-phosphorus using bulk chemical extraction confirms that substantial concentrations are present in

all the streams. Future plans include the use of genomic techniques to evaluate the presence of PAO in our samples.

P-criteria based upon Physiological Indicators

Alga biomass on natural (rock) substrata was consistently higher compared with that on artificial (tile) substrata, such that biofilms growing on tiles are more indicative of an early successional assemblage ($Z = -2.385$, $p = 0.017$, Table 1). Mean chlorophyll-a was 90.5 and 271.2 mg/m^2 on tile and rocks, respectively. Based on these relative differences between substrate biomass, we can reasonably categorize biofilm rock assemblages as 'late' succession communities and biofilm tile assemblages as 'early' succession (cf. Dent and Grimm 1999).

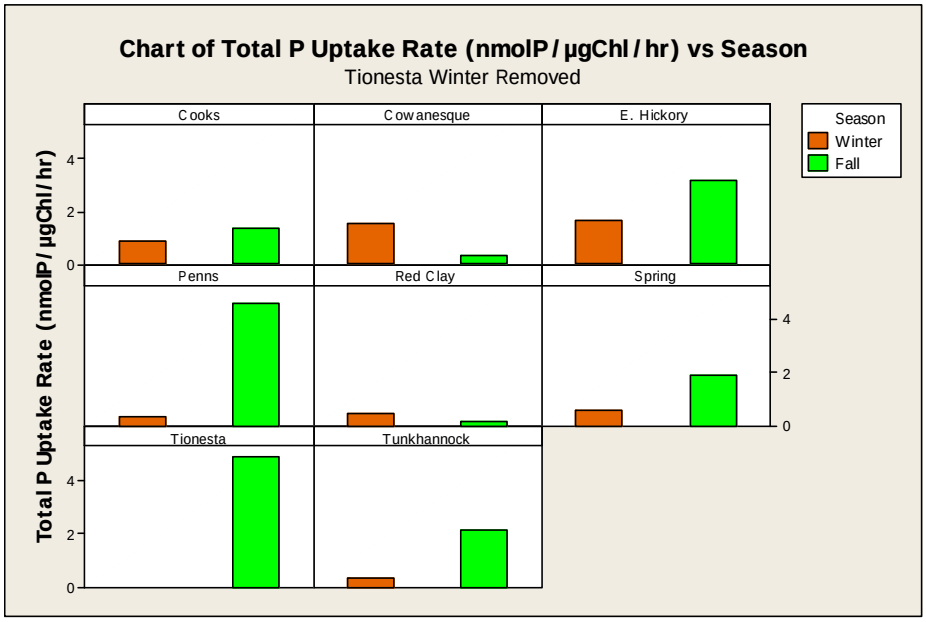
As anticipated, P uptake and APA was be positively correlated with each other as indicators of P limitation, and was negatively correlated with the productivity indicators. Four independent measures of biofilm nutrient metabolism were measured on tiles at each of the eight stream sites: C14 uptake (mgC µgChl-a^{-1} day^{-1}), P uptake (nmol P µg Chl-a^{-1} hr^{-1}), alkaline phosphatase activity (APA; nmol P µg Chl-a^{-1} hr^{-1}), and nitrate reductase (NR; nmol NO_2^- µg Chl-a^{-1} hr^{-1}). $Log_{10}(1+x)$ transformed site means for two sampling dates (n=16) were tested for correlation with each other and with two indicators of stream productivity – conductivity (µS/cm) and benthic biomass on rocks as chlorophyll-a (mg Chl-a m^{-2}) – using a correlation matrix in SPSS.

Table 2. Correlation matrix.

		Conductivity	Benthic Chl-a	C^{14}	P Uptake	APA	NR
Conductivity	Pearson Correlation	1	.505*	-.048	-.598*	-.562*	-.070
	Sig. (2-tailed)		.046	.865	.019	.029	.805
	N	16	16	15	15	15	15
Benthic Chl-a	Pearson Correlation	.505*	1	-.482	-.750**	-.665**	-.558*
	Sig. (2-tailed)	.046		.069	.001	.007	.030
	N	16	16	15	15	15	15
C14	Pearson Correlation	-.048	-.482	1	.620*	.624*	.771**
	Sig. (2-tailed)	.865	.069		.014	.013	.001
	N	15	15	15	15	15	15
P Uptake	Pearson Correlation	-.598*	-.750**	.620*	1	.903**	.719**
	Sig. (2-tailed)	.019	.001	.014		.000	.003
	N	15	15	15	15	15	15
APA	Pearson Correlation	-.562*	-.665**	.624*	.903**	1	.789**
	Sig. (2-tailed)	.029	.007	.013	.000		.000
	N	15	15	15	15	15	15
NR	Pearson Correlation	-.070	-.558*	.771**	.719**	.789**	1
	Sig. (2-tailed)	.805	.030	.001	.003	.000	

	N	15	15	15	15	15	15
*. Correlation is significant at the 0.05 level (2-tailed).			Positive correlation				
**. Correlation is significant at the 0.01 level (2-tailed).			Negative correlation				

As predicted, APA and P uptake had a strong positive correlation (Pearson correlation = 0.903, *p*= 0.000, n=15) and both variables had a negative correlation to conductivity and benthic chl-a (See Table 2). Interestingly, both P variables also had positive correlations with C^{14} uptake and NR, indicating that metabolism of C, N, and P may be closely linked.



A one-way ANOVA of total P uptake rate (nmolP/µgChl-a/hr) versus season indicated that those biofilms growing during the fall season were capable of greater realized P uptake compared to those biofilms in the winter season (F= 4.55, *p*= 0.05). This suggests that biofilms occurring in streams during the fall season provide a greater sink for stream P and may better restrain downstream nutrient transports.

STUDENTS & POSTDOCS SUPPORTED

Melissa May, MS Candidate, School of Forest Resources, Penn State University
Keith Price, PhD Candidate, School of Forest Resources, Penn State University
Erin Cafferty, Undergraduate, Environmental Resources Management Program, Penn State.

PUBLICATIONS

Carrick, H.J. 2010. Benthic algae-nutrient relationships in Mid-Atlantic streams. *Limnology and Oceanography*, In preparation.

PRESENTATIONS AND OTHER INFORMATION TRANSFER ACTIVITIES

Price, KJ and HJ Carrick. (2010) Biofilm Phosphorus Assimilation along a Stream Productivity Gradient: an In Situ Experiment. *Poster Presentation*. Pennsylvania Water Symposium. State College, PA.

Price, KJ and HJ Carrick. (2010) Influence of Stream Trophic State on Phosphorus Assimilation by Benthic Biofilms: Implications for Nutrient Management. *Invited Oral Presentation*. Pennsylvania Lake Management Society 20th Annual Conference. State College, PA.

Price, KJ and HJ Carrick. (2010) Assessing the Effects of Techniques used in Benthic Biofilm Phosphorus Uptake Studies. *Poster Presentation*. Gamma Sigma Delta Annual Graduate and Undergraduate Research Expo. State College, PA.

May, M and HJ Carrick. (2010) Nutrient effects on biofilms in PA streams: Linking biological indicators to land use. *Poster Presentation*. Pennsylvania Water Symposium. State College, PA.

May, M and HJ Carrick. (2010) Assessing nutrient limitation in streams: Correspondence between alternative measures of biofilm nutrient status. *Oral Presentation*. Pennsylvania Lake Management Society 20th Annual Conference. State College, PA.

AWARDS

Price, KJ and HJ Carrick. (2010) Poster Award. Pennsylvania Water Symposium.

ADDITIONAL FUNDING ACQUIRED USING USGS GRANT AS SEED MONEY

(source, amount, starting and ending dates, title)

Drs. Carrick and Regan are collaborating on a proposal to extend this work. The proposal will be submitted to the National Science Foundation for the December call in 2010. The proposal will be a three-year project.

PHOTOS OF PROJECT.